UNITED STATES PATENT APPLICATION

TITLE: IMPROVED SURGE SUPPRESSION APPARATUS INCLUDING AN LC NEUTRAL-GROUND FILTER

INVENTOR: Bahram Mechanic and Tooraj Faridi

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an electrical protective filter apparatus or transient voltage surge suppressor (TVSS) apparatus for protecting electrically powered devices from transient voltages such as office equipment or any microprocessor-based equipment.

[0002] More particularly, the present invention relates to an electrical protective filter apparatus or transient voltage surge suppressor (TVSS) apparatus for protecting electrically powered devices from transient voltages in a three-lead, single phase, power supply from a power distribution network, where the apparatus includes at least one LC filter circuit with the inductive component of the LC filter circuit disposed in the ground lead and the capacitive component between neutral and ground lead after the inductive component toward device and method for protecting such devices.

2. Description of the Related Art

[0003] Numerous types of office equipment used in recent years contain electronic chips or components which are sensitive to voltage surges or transients in power furnished by a power distribution network provided by utility companies. Examples of such types of office equipment include computers, facsimile machines, photocopiers and the like. Apparatus known as power filters or transient voltage surge suppressors have been developed to protect these types of office equipment from such power surges or transients. U.S. Pat. No. 5,721,661, of which applicant is inventor, is one form of such a power filter.

[0004] Office buildings and other places including such sensitive equipment often use a or center-tap power distribution system. There are several advantages of such distribution systems: (1) they allow more power to be delivered to a site, (2) they are more easily distributed, and (3) they allow two voltage levels (such as 120 volts and 240 volts) to be easily delivered. These advantages afford the customers greater flexibility in equipment type and usage and provide for a more cost effective way for an electric utility to transmit power to customers. In three phase or center tap power distribution system, if a ground wire or a neutral wire connection in the distribution grid is lost,

voltage levels provided in the network may increase up to a double level. Such voltage increases are not uncommon and can result in 120 V rated equipment rated being subjected to up to 240 volts resulting in potential damage to a surge protection component, firing of the TVSS unit or direct damage to the electrical equipment.

[0005] So far as is known, it was typical to use relatively inexpensive thermal fuses for protective purposes in these situations. These fuses would typically open after response to excess heat for periods of from couple of seconds to several minutes. It may protect the TVSS against firing after burn out, but sensitive electronic chips and circuits of connected equipment were not capable of withstanding such excessive voltage levels for even short fractions of a second, such as a few milliseconds.

[0006] Although several surge protection devices are currently sold into the market that rely on power interruptions circuitry such as those described in United States Pat. Nos.: 6,229,682 and 6,560,086, incorporated herein by reference, there is still in the art for improved surge suppression apparatuses that will improve power supply to critical microprocessor-based equipment and simultaneously reduce the risk of transient voltage damage to the equipment. New digital equipment need more filtration between neutral and ground leads to function smoothly because of more complex and low operating voltage (2.3V) microprocessors and need noise between neutral and ground leads be below 0.5V.

SUMMARY OF THE INVENTION

[0007] The present invention provides a new and improved protective apparatus for electrical devices connected to a three-lead, single phase power supply from a power distribution network, where the apparatus includes at least one neutral-ground LC filter circuit, where the inductive component (L) of the LC filter circuit is disposed in the ground lead and the capacitive component (C) is connected between the neutral and ground leads after the inductive component toward the device. The LC filter circuit is adapted to substantially reduce ground noise or noise between ground and neutral. By disposed in the ground lead, the inventors mean that the inductor is in series with the ground lead and not connected between ground and either of the other two leads.

[0008] The present invention also provides a new and improved protective apparatus for electrical devices connected to a three-lead, single phase power supply from a power distribution network, where the apparatus includes at least one neutral-ground LC filter circuit with the inductive component of the LC filter circuit disposed in the ground lead and the capacitive component

connected between the neutral and ground leads after the inductive component toward the device and a plurality of protective circuits interposed between hot and neutral, hot and ground and neutral and ground leads.

[0009] The present invention also provides a protective circuit having hot, neutral, and ground leads arranged to be placed between corresponding utility hot, neutral and ground leads of a power utility outlet of a power distribution network and corresponding device hot, neutral and ground leads of at least one electrical and/or electronic device, the protective circuit including at least one LC filter including at least one inductor disposed in the circuit ground lead and at least one capacitor connected between the circuit neutral and ground leads after the inductor toward the device, where the at least one LC filter circuit component is adapted to reduce or eliminate ground noise or noise between ground and neutral leads transmitted to the devices. The protective circuit may optionally also include neutral-ground voltage surge protective components.

[0010] The present invention also provides a new and improved protective apparatus for electrical devices connected to a power distribution network, where the apparatus includes at least one neutral-ground LC filter circuit with the inductive component of the LC filter circuit disposed in the ground lead and at least one capacitive component connected between the circuit neutral and ground leads after the inductor toward the device. The apparatus can also include hot to neutral voltage surge protective components, hot to ground voltage surge protective components, and a neural to ground voltage surge protection/filtration components. The apparatus also includes a relay circuit **R**, a voltage threshold sensing circuit **T** and indicator circuits **S1** and **S2**, where the relay circuit **R** is designed to protect components of the apparatus and/or to protect the electronic and/or electrical devices connected thereto or both from abnormal power conditions including over voltages, transients, loss of ground, polarity reversals or any other abnormal power supply condition. Although the threshold voltage can be set at any voltage over the standard supply voltage (120V US and 240V non-US), generally, the threshold voltage is set between about 10% and about 50% over standard supply voltage, preferably, between about 15% and about 30%, and particularly, between about 20% and about 25% above the standard supply voltage.

[0011] The present invention provides a method for protecting an electronic and/or electrical device connected to a three-lead, single phase power supply from a power distribution network including the step of interposing between an outlet of the network and the electronic and/or electrical device a protective apparatus of this invention.

DESCRIPTION OF THE DRAWINGS

[0012] The invention can be better understood with reference to the following detailed description together with the appended illustrative drawings in which like elements are numbered the same:

[0013] **Figures 1A** depicts a block schematic diagram of a preferred embodiment of a protective circuit apparatus of this invention;

[0014] **Figure 1B** depicts a block schematic diagram of a preferred embodiment of a protective circuit apparatus of this invention including a UPS interposed between the protective circuit apparatus and a device;

[0015] **Figure 1C** depicts a block schematic diagram of a preferred embodiment of a protective circuit apparatus of this invention including a UPS interposed between the protective circuit apparatus and a device with a capacitive component between neutral and ground interposed between the UPS and the device;

[0016] **Figure 2A** depicts a schematic diagram of a preferred embodiment of a protective apparatus of this invention including an LC filter component to filter noise between neutral and ground;

[0017] **Figure 2B** depicts a schematic diagram of a preferred embodiment of a protective apparatus of this invention which filters noise between neutral and ground leads and also including an LC filter component with an inductor in the hot lead to filter noise between hot and neutral and between hot and ground leads;

[0018] **Figure 2C** depicts a schematic diagram of an alternate preferred embodiment of a protective apparatus of this invention which filters noise between neutral and ground leads and also including an LC filter component with an inductor disposed in the neutral lead to filter noise between hot and neutral and between hot and ground leads;

[0019] **Figure 2D** depicts a schematic diagram of an alternate preferred embodiment of a protective apparatus of this invention which filters noise between neutral and ground leads and also including an LC filter component with an inductor in the hot lead and an inductor in the neutral lead to filter noise between hot and neutral and between hot and ground leads;

[0020] **Figure 2E** depicts a schematic diagram of an alternate preferred embodiment of a protective apparatus of this invention including a plurality of sequentially connected LC filter components to filter noise between neutral and ground leads and also including an LC filter component with an inductor in the hot lead and/or an inductor in the neutral lead to filter noise between hot and neutral and between hot and ground leads; and

[0021] **Figure 3** depicts a schematic diagram of another preferred embodiment of a protective apparatus of this invention including a plurality of switches adapted to protect the electronic and/or electrical device and each of the protective circuit components including at least one LC filter having the inductive element disposed in the ground lead at a capacitive element between the neutral and ground leads after the inductive element toward the device.

DETAILED DESCRIPTION OF THE INVENTION

[0022] The inventors have found that a surge suppression or TVSS apparatus can be constructed for protecting electronic and/or electrical device in a three-lead, single phase power supply from a power distribution network, where the apparatus includes at least one neutral-ground LC filter circuit, where the inductive element is disposed in the ground lead on the utility side of the capacitive component. T he apparatus can also be constructed with a relay component to disconnect the capacitive component of the LC filter circuit in the event of an abnormality such as a loss of ground, reversal of hot and neutral leads, over voltage and any other similar abnormality in the provided power. The apparatus can also include a voltage threshold sensing component, indicator components and voltage surge protection/filtration components between hot and neutral and between hot and ground, and between neutral and ground, where the components act cooperatively to protect electronic and/or electrical devices attached thereto from transients and/or over voltages.

[0023] The present invention broadly relates to a surge suppression apparatus for protecting electronic and/or electrical device in a power distribution network including at least one neutral-ground LC filter circuit having the inductive element disposed in the ground lead and the capacitive component between the neutral and ground lead after the inductive component toward the device and where the LC filter circuit is adapted to substantially reduce or eliminate ground noise or noise between ground and neutral and when coupled with a relay circuit that can disconnect the capacitive component of the LC filter circuit, the apparatus also reduces ground leakage currents.

[0024] The present invention broadly relates to a method for protecting electronic and/or electrical device in a power distribution network including the step of installing an apparatus of this invention between an outlet in the network and an electronic and/or electrical device.

[0025] The present invention relates to a new and improved protective circuit or transient voltage suppressor for electrical and electronic and/or electrical devices. The protective apparatus includes at least one neutral-ground LC filter having the inductive component disposed in the ground lead and the capacitive component between the neutral and ground lead after the inductive component toward

the device. The apparatus can also include other LC filters with the inductors in series with hot and/or neutral leads and capacitors between the hot and neutral leads and voltage surge protecting circuits and clamping devices such as MOV, gas tube, Transil, and Sidactor between any pair of leads. In one preferred embodiment, the present invention includes a differential transformer with one winding in series with circuit hot lead and one winding in series with the circuit neutral leads. The preferred embodiment of the electrical device may take the form of a computer, a copier, a facsimile machine or the like having voltage surge or transient sensitive electronic components, such as computer chips and other electrical component.

[0026] The apparatuses of this invention are designed to be interposed between an outlet of a distributed power network and electronic or electrical devices sensitive to abnormal power conditions. Such abnormal power conditions include, without limitation, over voltages, transient voltage spikes, disconnected ground leads, polarity reversals of hot and neutral leads, and other similar abnormalities that can result in damage to sensitive electronic or electrical devices and device components.

[0027] Referring now to **Figure 1A**, a block schematic diagram of a preferred embodiment of an apparatus of our invention, generally **100**, is shown to include a power distribution network outlet **102** having utility hot, neutral, and a ground leads **104a**, **106a**, and **108a**, respectively. The apparatus **100** also includes a surge apparatus **110** having apparatus hot, neutral and ground leads **104b**, **106b**, and **108b**, respectively, connected to the corresponding utility leads **104a**, **106a**, and **108a**. The apparatus **110** is interposed between the utility outlet **102** and an electrical or electronic device **112** having device hot, neutral and ground leads **104c**, **106c**, and **108c**, respectively, connected to the corresponding apparatus leads **104b**, **106b**, and **108b'**, where the prime designation is used to indicate that lead has the inductive component **116** disposed in the ground lead. The apparatus **110** includes a neutral-ground LC filter circuit **114** having the inductive component **116** disposed in the apparatus ground lead **108b** and the capacitive component **118** connected between the neutral and ground leads **106b** and **108b'** and located on device side **120** of the inductive component **116**. The LC filter **114** is designed to substantially reduce or eliminate neutral to ground noise transmitted to the device **112**.

[0028] Looking at **Figure 1B**, a block schematic diagram of another preferred embodiment of an apparatus of our invention integrated with an UPS device, generally **100**, is shown to include a power distribution network outlet **102** having utility hot, neutral, and a ground leads **104a**, **106a**, and **108a**,

respectively. The apparatus **100** also includes an apparatus **110** having circuit hot, neutral and ground leads **104b**, **106b**, and **108b**, respectively, connected to the corresponding utility leads **104a**, **106a**, and **108a**. The apparatus **110** is interposed between the utility outlet **102** and an uninterruptible power supply (UPS) device **112** having UPS hot, neutral and ground leads **104c**, **106c**, and **108c**, respectively, connected to the corresponding circuit leads **104b**, **106b**, and **108b'**. The UPS device **112** is interposed between the apparatus **110** and an electrical or electronic device **114** having device hot, neutral and ground leads **104d**, **106d**, and **108d**, respectively, connected to the corresponding UPS output leads **104c'**, **106c'**, and **108c'**. The apparatus **110** includes a neutral-ground LC filter circuit **116** having the inductive component **118** disposed in the apparatus ground lead **108b** and the capacitive component **120** connected between the neutral and ground leads **106b** and **108b'** and located on device side **122** of the inductive component **118**. The LC filter **116** also includes a relay switch **124** adapted to disconnect the capacitive component **120** if an abnormal condition exists in the supplied power. The LC filter **116** is designed to substantially reduce or eliminate neutral to ground noise transmitted to the electrical device **114**. The UPS device **112** can be any UPS device used in the industry.

[0029] Looking at **Figure 1C**, a block schematic diagram of another preferred embodiment of an apparatus of our invention integrated with an UPS device, generally **150**, is shown to include a power distribution network outlet **152** having utility hot, neutral, and a ground leads **154a**, **156a**, and **158a**, respectively. The apparatus **150** also includes an apparatus **160** having apparatus hot, neutral and ground leads **154b**, **156b**, and **158b**, respectively, connected to the corresponding utility leads **154a**, **156a**, and **158a**. The apparatus **160** is interposed between the utility outlet **152** and an UPS device **162** having UPS hot, neutral and ground leads **154c**, **156c**, and **158c**, respectively, connected to the corresponding circuit leads **154b'**, **156b'**, and **158b'**. The UPS device **162** is interposed between the apparatus **160** and an electrical or electronic device **164** having device hot, neutral and ground leads **154d**, **156d**, and **158d**, respectively, connected to the corresponding UPS output leads **154c'**, **156c'**, and **158c'**. The apparatus **150** also includes a capacitive component **166** between neutral and ground leads **156c'** and **158c'** on the output of the UPS device **162**. The apparatus **160** includes a neutral-ground LC filter circuit **168** having an inductive component **170** disposed in the apparatus ground lead **158b** and an optional capacitive component **172** connected between the neutral and ground leads **156b'** and **158b'** and located on device side **174** of the inductive component **170**. The apparatus **160**

also includes two relay switches **176a&b** adapted to disconnect the hot and neutral leads **154b** and **156b**, respectively, if an abnormal condition exists in the supplied power. It should be recognized that the leads **154b'** and **156b'** are so designated because they are on the device side of the switches **176a&b**. The LC filter **168** is designed to substantially reduce or eliminate neutral to ground noise transmitted to the electrical device **164**.

[0030] Referring now to **Figure 2A**, a preferred embodiment of an apparatus of this invention, generally **200**, is shown to include three leads, a hot lead **202**, a neutral lead **204** and a ground lead **206**. The three leads **202**, **204** and **206** are designed to be connected to a single phase outlet of a power distribution network (not shown). The apparatus **200** may optionally include a protective fuse **208** for protecting components of the apparatus **200**. The apparatus **200** includes at least one LC filter adapted to substantially reduce noise between the neutral and ground leads **204b** and **206b**, with an inductive component L **258** disposed between the ground lead **206** and **206b** and a capacitive component C **260** between the neutral lead **204b** and ground lead **206b** after the inductive component L **258** toward the device as described more fully herein. The apparatus **200** can also includes voltage surge protection/filtration circuits between the hot and neutral leads **202** and **204**, and/or between the hot and ground leads **202a** and **206**, and/or between the neural and ground leads **204** and **206**, as described more fully herein. The apparatus **200** can also include noise reduction filters for reducing noise between the hot and neutral leads and/or between the hot and ground leads. The apparatus **200** can also includes a relay circuit **R**, a voltage threshold sensing circuit **T** and indicator circuits **S1** and **S2** for connecting or disconnecting components or leads in the apparatus **200** in response to an abnormal power condition.

Relay Circuit - R

[0031] The relay circuit **R** includes a first relay **210** and a second relay **212** connected between the hot lead **202a** and neutral lead **204**. As is conventional, a protective diode **214** and a filter capacitor **216** are connected in parallel across the relays **210** and **212**. In the event of an abnormality in the power network, the switches of the relay circuit **R** are designed to disconnect the power going to the electrical device connected to the protective apparatus **200**. In the event of an abnormality in the power network, the switches of the first relay **210** and second relay **212** also protect the voltage surge protection/filtration circuits against high voltages between any pair of the leads **202a**, **204**, and **206**.

[0032] The first relay **210** controls a position or state of a first switch **210s**. The switch **210s**

transitions between an opened state (as shown) and a closed state depending on current flow through the relay circuit **R**, where the closed state connects two parts **204** and **204b** of the neutral lead. Thus, when the switch **210s** is in its opened state, the utility part **204** of the neutral lead is disconnected from the lead **204b** disrupting the continuity of the neutral lead **204**. As long as the ground lead **206** is electrically connected to the utility ground, and also, as long as the connection between the hot and neutral leads **202** and **204** to the hot and neutral leads of the network is not reversed, and as long as the voltage of the power network is normal as sensed by the threshold sensing circuit **T**, then the relay **210** receives current and the switch **210s** is in its closed position.

[0033] The second relay **212** of the relay circuit **R** includes controls a position or state of a second switch **212s**. The switch **212s** transitions between an opened state (as shown in **Figure 2A**) and a closed state depending on current flow through the relay circuit **R**, where the closed state connects two parts **202a** and **202b** of the hot lead **202**. Thus, when the switch **212s** is in its opened state, the utility part **202a** of the hot lead **202** is disconnected from the lead **202b** disrupting the continuity of the hot lead **202**. As long as the relay **212** is receiving electrical current, the switch **212s** is closed and electrical power is furnished to the lead **202b** of the hot lead **202**. If no current flows through the relay **212**, such as when the ground connection is interrupted, or polarity between the hot lead **202** and neutral lead **204** becomes reversed or an over voltage condition has occurred, the switch **212s** opens and no power is furnished to the lead **202b** of the hot lead **202** protecting the electronic device(s) connected to the apparatus **200** from voltage surges, over voltage or transients. The relays **210** and **212** also protect of apparatus circuit components against increased voltage.

<u>Threshold Sensing Circuit T</u>

[0034] The voltage threshold sensing circuit **T** is designed to detect when a voltage between the hot lead **202** and the neutral lead **204** from the distribution network exceeds a set or threshold voltage. The threshold voltage is established by a relative impedance of series connected resistors **218** and **220**. The threshold voltage may be adjusted by selecting different impedance values for the two resistors **218** and **220**, or by replacing either or both of the resistors **218** and **220** with variable resistors or rheostats. The sensing circuit **T** also includes a DC filter capacitor **222** connected in parallel with the resistor **218**. The resistor **220** is electrically connected to the neutral lead **204** by a resistor **226** and a diode **228**, which rectifies the AC voltage to DC.

[0035] A Zener diode **230** is electrically connected between the junction of the resistors **218** and **220**

and the resistor **233** to sense the utility voltage. As long as the utility voltage does not exceed the threshold voltage, the Zener diode **230** does not conduct. If the utility voltage exceeds the threshold voltage, then the Zener diode **230** begins to conduct and a transistor or other electrical or electronic switch **232** with biasing resistors **233** and **233a** begins to conduct. Obviously, the transistor **232** is normally held in a non-conductive state because the utility voltage is below the threshold voltage – the normal state.

[0036] A collector terminal **232c** of the transistor **232** is connected to a thyristor **234** at a gate **234g**, or other suitable electronic switch, such as a transistor, connected in series with the relays **210** and **212**. When the transistor **232** begins to conduct due to the utility voltage exceeding the threshold voltage, the current through a diode **236** and resistor **238** to the gate **234g** of the thyristor **234** is drawn to zero. The thyristor **234** is then switched to a non-conductor or off state and current flow through relays **210** and **212** is terminated. In this manner, the relays **210** and **212** become in the idle state and their switches **210s** and **212s**.

[0037] The thyristor **234** is normally biased to a conductive state and provides electrical current to relays **210** and **212** by a bias network **240** including an optional capacitor **241**, the diode **236**, the resistor **238** and another resistor **242**. Another diode **244** rectifies the AC to DC and a resistor **246** limits the current in the relays **210** and **212**, when the thyristor **234** is conductive and thus relays **210** and **212** are receiving current.

[0038] When the ground lead **206** and the hot and neutral leads **202** and **204** are properly connected to the power network, then a thyristor **234** is on. The relays **210** and **212** turn on setting the switches **210s** and **212s** to their closed positions connecting the neutral lead **204** to the neutral lead **204b** and the hot lead **202a** to the hot lead **202b**. In this manner, any power surges or transients between the any pair of leads are suppressed by the voltage protection/filtration circuits described below.

Voltage Protection/Filtration Circuits

[0039] The hot-neutral voltage protection/filtration circuit includes a plurality of voltage clamping elements **224** and **248a-c**, such as MOVs, gas tubes, Transils, Sidactors, or the like, connected between the hot lead **202a** or **202b** and the neutral leads **204** or **204b**. The voltage protection/filtration circuit also includes a capacitor **250** and an optional discharge resistor **252**.

[0040] The hot-ground voltage protection/filtration circuit includes a plurality of voltage clamping elements **254a-b** connected between the hot lead **202b** and the ground lead **206**.

[0041] The neutral-ground voltage surge protection/filtration circuit includes a plurality of voltage clamping elements **256a-c** connected between the neutral leads **204** and **204b** and the ground lead **206**. The neutral-ground voltage surge protection/filtration circuit also includes an LC filtering circuit **LC** including an inductive component **L** and a capacitive component **C** after the inductive component **L**. The inductive component **L** includes an inductor **258**. The capacitive component **C** includes a main capacitor **260** or an optional pair of series connected capacitors **262a&b** connected between the neutral lead **204b** and the ground **206b** and an optional discharging resistor **264**. The neutral-ground voltage surge protection/filtration circuit can also include two optional Transils **266a-b** attached parallel to the voltage clamping device **256b** and **256c**, respectively.

[0042] Although particular voltage clamping elements as described in the circuits above, any other voltage clamping element or combination of such elements can be used as well including, without limitation, MOVs, gas tubes, Transils, Sidactors, or the like.

Indicator Circuits S1 and S2

[0043] The first indicator circuit **S1** is an alarm indicating circuit and includes a photo-emitter **268**, such an LED, connected in series with the switch **212s** to the hot lead **202a** and also through an indicator circuit diode **270** and an indicator circuit resistor **272** to the neutral lead **204**. The alarm photo-emitter **268** is energized when the switch **212s** is in its opened position as shown in **Figure 2A** and illuminates indicating the alarm condition.

[0044] The second indicator circuit **S2** is a normal indicating circuit and includes a photo-emitter **274**, such as an LED, connected between the hot lead **202b** and through a second indicator circuit diode **276** and a second indicator circuit resistor **278** to the neutral lead **204b**. During normal operation, when the relays **210** and **212** are receiving current, the switches **210s** and **212s** are in their closed positions and the normal photo-emitter **274** is energized and power flows through the apparatus **200** to the electrical devices attached thereto.

[0045] Referring now to **Figure 2B**, another preferred embodiment of an apparatus of this invention, generally **200**, is shown to include all the elements of **Figure 2A**, with the addition of an inductive component **L1** disposed in the hot lead **202b**. In this embodiment, the inductive component **L1** includes an inductor **280** connected in series in the hot lead between the hot leads **202b** and **202c**. The inductive component **L1** in cooperation with the capacitor **250** and the resistor **252** forms a hot-neutral LC filter designed to substantially reduce noise between the hot lead **202c** and the neutral

lead **204b** also the inductive component **L1** in cooperation with the capacitors **250** and **260** and inductor **258** forms a hot-ground LC filter designed to substantially reduce noise between the hot lead **202c** and the ground lead **206b**.

[0046] Referring now to **Figure 2C**, another preferred embodiment of an apparatus of this invention, generally **200**, is shown to include all the elements of **Figure 2A**, with the addition of an inductive component **L2** disposed in the neutral lead **204b**. In this embodiment, the inductive component **L2** includes an inductor **282** connected in series in the neutral lead between the neutral leads **204b** and **204c**. The inductive component **L2** in cooperation with the capacitor **250** and the resistor **252** forms an alternate hot-neutral LC filter designed to substantially reduce noise between the hot lead **202b** and the neutral lead **204c**.

[0047] Referring now to **Figure 2D**, another preferred embodiment of an apparatus of this invention, generally **200**, is shown to include all the elements of **Figure 2A**, with the addition of a first windingof a transformer **TR1** or single inductor **284a** disposed in the hot lead between the hot leads **202b** and **202c** and a second winding of the transformer **TR1** or a single inductor **284b** disposed in the neutral lead between the neutral leads **204b** and **204c**. The two windings of the transformer **TR1** can be positioned in series or differential.

[0048] Referring now to **Figure 2E**, another preferred embodiment of an apparatus of this invention, generally **200**, is shown to include all the elements of **Figure 2A**, with the addition of the transformer TR1 as described in **Figure 2D**. Additionally, in this embodiment, the neutral-ground protection/filtration circuit includes a plurality of LC filter components **LCa-c**, each LC filter **LCa-c** including an inductive component **La-c** disposed in the ground lead and a capacitive component **Ca-c** positioned on the device side of its corresponding inductive component **La-c** and neutral lead **204b**. Each inductive component **La-c** includes an inductor **258a-c** and each capacitive component **Ca-c** includes a capacitor **260a-c**. The neutral-ground protection/filtration circuit also includes an optional discharging resistor **264**, which discharges the capacitors **260a-c**. The neutral-ground protection/filtration circuit also i ncludes a Transil **286** and a Sidactor **288** connected in series between the neural lead **204b** and the ground lead **206** configured taking the place of a voltage clamping device.

[0049] Referring now to **Figure 3**, another preferred embodiment of an apparatus of this invention, generally **300**, is shown to include three leads, a hot lead **302**, a neutral lead **304** and a ground lead

306. The three leads **302**, **304** and **306** are designed to be connected to a single phase outlet of a power distribution network (not shown). The apparatus **300** may optionally include a protective fuse **308** for protecting components of the apparatus **300**. The apparatus **300** includes at least one LC filter adapted to substantially reduce noise between the neutral and ground leads **304a** and **306a**, with an inductive component L **358** disposed between the ground leads **306** and **306a** and a capacitive component C **360** in series with the switch **212s** is connected between the neutral lead **304a** and ground lead **306a** after the inductive component L **358** toward the device as described more fully herein also a resistor **362** and a clamping device **363** are parallel with the capacitor **360**. The apparatus **300** can also include voltage surge protection/filtration circuits between the hot and neutral leads **302a** and **304a**, and/or between the hot and ground leads **302a** and **306**, and/or between the neural and ground leads **304** and **306**, as described more fully herein. The apparatus **300** can also include noise reduction filters for reducing noise between the hot and neutral leads and/or between the hot and ground leads. The apparatus **300** also includes a relay circuit **R**, a voltage threshold sensing circuit **T** for connecting or disconnecting components in the apparatus **300** in response to an abnormal power condition, where the relay circuit **R** and the voltage threshold sensing circuit **T** are as described above, except that the element labels are analogous 300 series numbers and also the relay circuit **R** controls different switches with the relay **310** controlling two switches. The apparatus **300** includes indicator circuits **S1** and **S2**, where the indictor circuits **S1** and **S2** as described above, except that the element labels are again analogous 300 series numbers.

Voltage Protection/Filtration Circuits

[0050] The hot-neutral voltage protection/filtration circuit includes one voltage clamping elements **324** between the hot lead **302a** and neutral lead **304**, also a plurality of voltage clamping devices **348a-b** such as MOVs, gas tubes, Transils, Sidactors, or the like, in series with the switch **310s1** are connected between the hot lead **302a** and the neutral leads **304** or **304a**. The voltage protection/filtration circuit also includes a capacitor **350** and a discharge resistor **352** parallel with the voltage clamping device **348a&b**.

[0051] The hot-ground voltage protection/filtration circuit includes a voltage clamping elements **354** in series with the switch **310s1** connected between the hot lead **302a** and the ground lead **306**.

[0052] The neutral-ground voltage surge protection/filtration circuit includes a plurality of voltage clamping elements **356a** connected between the neutral leads **304** and the ground lead **306** and also

includes a voltage clamping **356b** in series with the switch **310s2** connected between the neutral lead **304** and the ground lead **306.** The neutral-ground voltage surge protection/filtration circuit also includes an LC filtering circuit LC including an inductive component L disposed between the ground leads **306** and **306a,** a capacitive component C in series with the switch **312s** connected between the neutral and ground leads **304a** and **306a** after the inductive component L. The inductive component L includes an inductor **358**. The capacitive component C includes a capacitor **360** and an optional discharging resistor **362** in parallel with the capacitor **360** also include a Transil **363** or a combination of a Transil in series with a Sidactor in parallel with the capacitor **360**. As shown in **Figure 3**, the capacitive component C of the LC filter of the neutral-ground protection/filtration circuit disconnected (inactive) when the switch **312s** is opened due to an abnormal condition in order to limit the flow of current to the ground **306** and connected (active) when the switch **312s** is closed.

[0053] It should be noted that each of the various voltage clamping devices, as well as the electrical filter elements, such as capacitors and inductors, in the apparatuses of this invention are connected between the neutral lead and the ground lead, between hot and ground and between neutral and ground. In this manner, an undesirable effect, such as neutral-ground (or common mode) noise, hot-neutral noise and hot-ground noise and transient spikes are filtered and suppressed by the protection/filtration apparatus components.

[0054] It should be understood also that the relays and may be separately connected individually between the utility parts of the hot lead and neutral lead, respectively, rather than in series as shown in the Figures. In this separate connection format, each of the relays are provided with a separate thyristor or other electronic switch functioning like the thyristor. Each such separate thyristor or electronic switch is of course provided with its own corresponding bias network of the type described above. Also, if desired, one relay with two sets of switch arm contacts may be used as an alternate. Moreover, the protection/filtration circuits of this invention can be constructed in a number of different configuration and still include an LC filter circuit between the neutral and ground leads with the inductor in the ground lead.

[0055] All references cited herein are incorporated by reference. While this invention has been described fully and completely, it should be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. Although the invention has been disclosed with reference to its preferred embodiments, from reading this description those of skill in the art may appreciate changes and modification that may be made which

do not depart from the scope and spirit of the invention as described above and claimed hereafter.